

## **Research Brief for DOE/IHEA Process Heating Materials Forum**

**Research Title:**        **Low Cost Ceramic Composite Fan Materials**

**Industry Need:** There is a need for materials with reduced weight, increased corrosion and creep resistance, and reduced thermal inertia to realize the economic benefits associated with longer service lives and reliable performance of fans in the operation of heat treating furnaces. The availability of heat treating furnace fans with improved temperature capability would also have a positive environmental impact because in many cases, by allowing higher processing temperatures and eliminating the need for ancillary cooling equipment, it would result in higher process efficiency. These high temperature fans would lower fuel consumption, increase productivity, and improve quality of finished parts in the process heat industry. The proposed research would examine the development of low cost ceramic composite materials for fans.

**Existing Research:** Ceramic composites have been developed through numerous studies and programs, and in many cases, very good properties were achieved. However, the use of the composites in industrial application was limited due to their prohibitively high cost. The requirements for fan blade materials in metal heat-treating furnaces include appropriate mechanical properties at the operating temperature ( $\sim 900^{\circ}\text{C}$ ), corrosion resistance to the operating environment, and low cost.

An earlier study, at ORNL, found that silicon slurry infiltration into a carbon fiber mat (of the type used for furnace insulation) followed by a high temperature heat treatment resulted in the formation of SiC. The density of material was  $\sim 1.1 \text{ g/cm}^3$  and more interesting is that the much of the fiber morphology was retained. Panels of approximately 8" x 8" x 0.2" were fabricated in this study. The main interest of this research was for microwave absorption, so no further physical property characterization was done. However, the strength of the material was sufficient so that it was used as furnace structural components up to  $\sim 1400^{\circ}\text{C}$  in nitrogen.

ORNL researchers have investigated the effect of temperature, stress and industrial environments on the mechanical properties, durability and reliability of continuous fiber-reinforced ceramic matrix composites (CFCCs). CFCCs are a relatively new class of materials with low density and the potential for retaining strength, exhibiting tough behavior and having long service lives at elevated temperatures in extreme environments. ORNL researchers have played a pivotal role in the development of standardized test methods for the evaluation of these materials, have designed and developed experimental tests facilities for their thermomechanical evaluation in actual and simulated industrial environments, and have developed methods to predict their service life for arbitrary sets of operational conditions. ORNL researchers have collaborated with various industrial partners and with COI-Ceramics, Inc. in particular, who in collaboration with Surface Combustion Inc., has developed CFCC fans for metal heat treating furnaces.

**Proposed Activity:** The purpose of this research activity is to develop composite materials with enhanced environmental resistance (high temperature, corrosion, and oxidation) through improvements in the material composition and/or processing. Although there will be two main approaches to this research, other innovative heating/densification processes such as microwave will also be examined. The two main approaches that are being considered are: (1) slurry infiltration and utilization of the high density infrared (HDI) sintering process; and (2) continuous fiber-reinforced ceramic matrix composite (CFCC) processing.

Processing innovations will focus on the use of slurries and the use of the HDI sintering process. Either traditional slurries (powder suspended in a solvent) or solutions composed of precursor materials can be utilized to infiltrate a carbon fiber mat. After infiltration, the HDI process can be used to densify the “slurry” within the matrix. The HDI process will enable a reactive approach, that would be rapid and cost effective, to the in-situ formation and densification of materials that are typically expensive or difficult to sinter.

Most of the existing work on the development of CFCC fans for heat treating furnaces has been focused on the use of Silicon Carbide (SiC) -based CFCCs. Although some SiC-based CFCCs possess outstanding properties, their relatively high-cost and lack of stability in some industrial environments has prompted the need to investigate alternative material systems. It is proposed, in collaboration with COI-Ceramics and other CFCC developers and manufacturers, to investigate the potential of all-oxide CFCCs, in particular, CFCCs with alumina or mullite matrices reinforced with mullite-alumina fibers. ORNL researchers would work with CFCC developers and manufacturers to develop the primary processing methods for reliable and cost-effective fabrication of CFCCs. In collaboration with CFCC manufacturers and end users, ORNL researchers will work on materials selection, optimization of fiber architecture based on various fan geometries and operating speeds, on the mechanical and environmental characterization of candidate materials, and on the evaluation of their durability and reliability in application-specific conditions. For promising material systems, the technology would be demonstrated in actual heat treating environment.

**Research Team:**

- Ronald Ott (lead contact)  
Oak Ridge National Laboratory  
Metals and Ceramics Division  
Materials Processing Group  
Infrared Processing Center  
Phone: (865) 574-5172  
Email: ottr@ornl.gov
  
- Beth Armstrong  
Surface Processing and Mechanics Group  
Phone: (865) 241-5862

- Craig Blue  
Materials Processing Group  
Phone: (865) 574-4351
- Edgar Lara-Curzio  
Mechanical Characterization and Analysis Group  
Phone: (865) 574-1749
- Terry Tiegs  
Materials Processing Group  
Phone: (865) 574-5173